FM BROADCASTING

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ACHIEVEMENTS: *Broadcasting and reception of an FM signal.*

PREREQUISITES: *this is a non-quantitative look at an FM signal, and a familiarity with the FM spectrum is not essential. Completion of the experiment entitled **AM Broadcasting** is assumed (where the TIMS broadcasting accessories were introduced).*

Introduction

In this experiment you will broadcast an FM signal to one or more remote TIMS SYSTEM UNITS. The message will initially be a single tone, but once the system is working, a speech or music message may be substituted.

At the transmitter the FM will be generated with a VCO. The receiver will use a non-synchronous demodulator.

An FM Generator

For this experiment you will use a VCO as the source of the FM signal. It will be set to operate on a carrier of about 100 kHz. It is not necessary, in this experiment, which is qualitative in nature, to calibrate the FM sensitivity of the VCO. Calibration of the VCO is described in the experiment entitled ***Introduction to FM using a VCO***.

The FM generator is modelled according to the scheme of Figure 1.

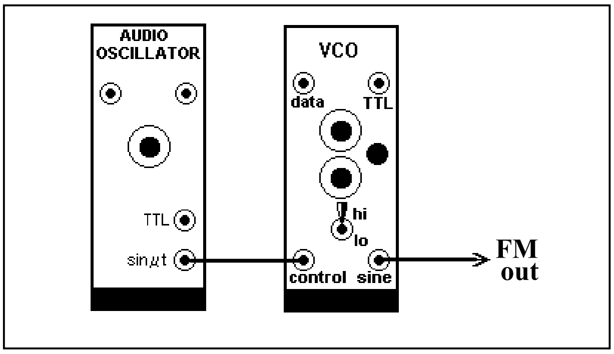

Figure 1: the FM generator.

T1 *obtain a VCO module. Before plugging it in, set the mode of operation to 'VCO' with the on-board switch. Set the front panel switch to 'HI', which selects the 100 kHz operating range.*

T2 *patch up the arrangement of Figure 1.*

T3 *set the frequency of the AUDIO OSCILLATOR to about 1 kHz.*

T4 *set the GAIN control of the VCO fully anti-clockwise. This control will be used to adjust the frequency deviation, which is now set to zero.*

T5 *use the front panel control f_o, of the VCO, to set the VCO frequency to about 100 kHz.*

You have just modelled an FM generator, or 'exciter'.

An FM Transmitter

The FM signal can be broadcast to one or more remote TIMS SYSTEM UNITS by connecting the output of the generator to a Tx ANTENNA via a BUFFER AMPLIFIER. The connections are shown in Figure 2.

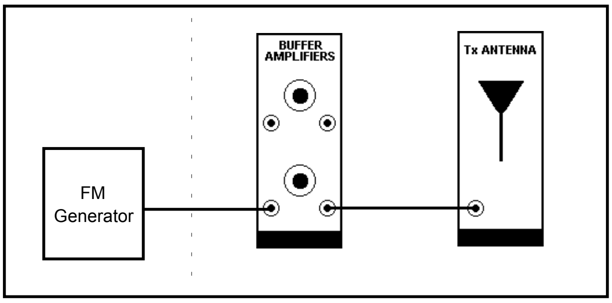

Figure 2: the FM Transmitter

T6 *with the FM generator providing an unmodulated carrier (set up in the previous Task), adjust the gain of the BUFFER AMPLIFIER of Figure 2 to provide a carrier output at TIMS STANDARD REFERENCE LEVEL.*

The FM transmitter is now set up, with zero frequency deviation.

An FM Receiver

For this FM broadcast experiment a receiver with a simple FM demodulator will be modelled.

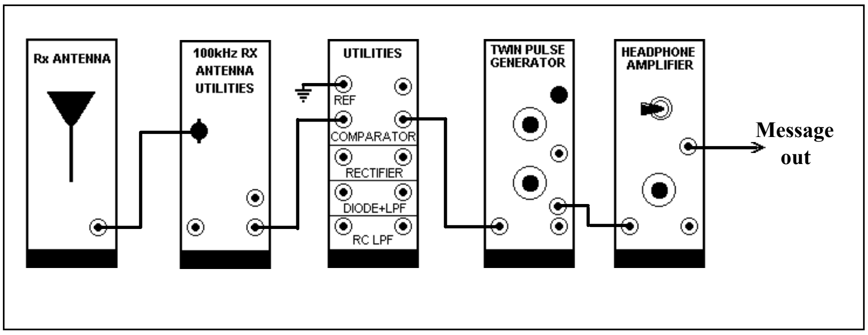

Figure 3: the complete FM receiver

T7 *patch up the arrangement of Figure 3.*

T8 *check that a 100 kHz is being received by observing. with the oscilloscope, the signal at the output of the 100 kHz Rx ANTENNA UTILITIES module. This should be an approximately 100 kHz sine wave at the TIMS STANDARD REFERENCE LEVEL. It will be accompanied by significant noise if the antennas are separated by more than a few metres. Check that the wanted signal is present by disconnecting the transmitting antenna from the transmitter. There should be a noticeable change to the oscilloscope picture.*

If it appears that there is no signal being received, then, after checking the models for correct patching:

- check that the axes of the two antennas are co-linear
- move the two antennas closer together (say less than 5 metres)
- increase the transmitter output with the BUFFER AMPLIFIER gain control

When finally a signal is received you are ready to set up the demodulator:

the zero-crossing-counter demodulator

A simple yet effective FM demodulator is one which takes a time average of the zero-crossings of the FM signal. Figure 4 suggests the principle.

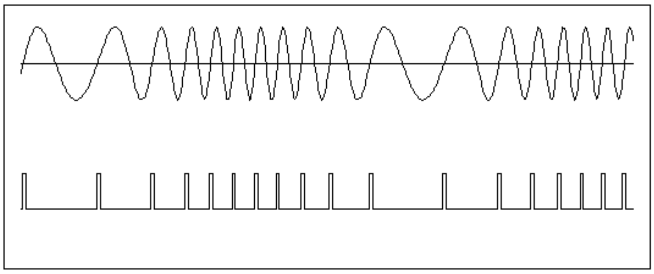

Figure 4: An FM signal, and a train of fixed-width pulses coincident with its zero-crossings.

Each pulse in this pulse train is of *fixed width*, there being one pulse per positive-going zero-crossing of the FM signal. This is a pulse-repetition-rate modulated signal. The pulse train is passed through a lowpass filter, which will perform an averaging operation. The rate of change of this average value is related to the message frequency, and the magnitude of the change to the message amplitude.

A model for achieving this result is included in Figure 3.

The TWIN PULSE GENERATOR is required to produce a pulse of fixed width at each positive-going zero-crossing of the FM signal. The TWIN PULSE GENERATOR is triggered by a positive-going TTL edge. This is generated, from the analog FM signal, by the COMPARATOR.

The width of the pulse output from the TWIN PULSE GENERATOR needs to be narrower than 10 μs if consecutive pulses are not to overlap [1].

The procedure for setting up the FM demodulator is described below.

T9 *make sure the frequency deviation at the transmitter is still set to zero by having the VCO gain control fully anti-clockwise. With the oscilloscope observe the output of the COMPARATOR. Ensure that the COMPARATOR has turned the received carrier into a rectangular pulse train at carrier frequency (about 100 kHz). The oscilloscope will need to be triggered to the pulse train itself. Depending on the received signal-to-noise ratio this pulse train may be blurred, but provided it is stable, then proceed to the next Task.*

T10 *observe the output of the TWIN PULSE GENERATOR with the oscilloscope . Adjust the pulses in the pulse train from the TWIN PULSE GENERATOR to such a width that consecutive pulses do not overlap. Since the carrier is approximately 100 kHz (period = 10 μs), then a suitable pulse width is about 5 μs. The oscilloscope will need to be triggered to the pulse train itself.*

It is now time to introduce some modulation at the transmitter.

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[1] ensure your module is marked 'V2' on the circuit board. Early models, produced before mid-1993, and not so marked, were unable to meet this requirement. Disable the Q2 output.

T11 *whilst observing the pulse train from the TWIN PULSE GENERATOR rotate the GAIN control of the VCO in a clockwise direction. The pulses to the right of the oscilloscope screen will become blurred, showing that the VCO is being frequency modulated.*

T12 *there should now be a signal, at message frequency, at the output of the LPF in the HEADPHONE AMPLIFIER. Observe this signal using the oscilloscope. The oscilloscope will need to be triggered to the signal itself. Listen to it with the headphones.*

note: the input signal to the HEADPHONE AMPLIFIER filter is at *TTL* level. It is TIMS practice, to avoid overload, not to connect a TTL signal to an analog input. Overload will probably not happen in this example, due to the nature of the particular circuitry employed. However, as a precaution, the large DC component in the TTL signal can be rejected by selecting the 'analog' output from the TWIN PULSE GENERATOR.

Now that the system appears to be working there are many tests and observations that can be carried out. For example:

- show that the amplitude of the message output from the demodulator varies with the message amplitude into the VCO. Is this a linear variation ?
- confirm that the frequency of the received message is the same as that transmitted.
- increase the frequency deviation at the transmitter with the GAIN control of the VCO. Does the received message remain undistorted over the full range of this control ? If not, why not ? Can you determine whether the distortion originates at the transmitter or the receiver ?
- does the amplitude of the message output from the demodulator vary with the pulse width from the TWIN PULSE GENERATOR. Is this a linear variation ? Over what range of widths does the message remain undistorted ? When, and why, does distortion occur ?
- reduce the transmitted signal amplitude, whilst both observing the signal at the output of the 100 kHz Rx ANTENNA UTILITIES module (both with and without the BPF) and listening to the received message from the demodulator.
- change the message at the transmitter from a single tone to speech, or music.

Tutorial Questions

Q1 *sketch the waveform of the 100 kHz FM signal when unmodulated, and when modulated with a single tone. Show the time scale.*

Q2 *what will the FREQUENCY COUNTER indicate when connected to the FM signal from the VCO ? Discuss possibilities.*

Q3 *whilst observing the pulse train from the TWIN PULSE GENERATOR, as the frequency deviation was increased, the pulses to the right of the oscilloscope screen became blurred, but not those on the extreme left. Explain.*

Q4 *what factors determined the chosen pulse width in the demodulator ? What would be the maximum possible acceptable width for this experiment ? Explain.*

Q5 *the output of the COMPARATOR is a train of pulses derived from the positive-going zero-crossings of the FM signal. Why not take the average of this train, rather than generate another one with the TWIN PULSE GENERATOR ?*

Q6 *a VCO offers a very simple method of generating an FM signal. Despite this simplicity, it is seldom used in FM communication or broadcasting systems. Suggest a reason.*